AD-A049 929 DEFENCE RESEARCH ESTABLISHMENT VALCARTIER (QUEBEC) F/G 20/5

SIMULTANEOUS FREQUENCY STABILIZATION AND INJECTION IN A TEA-CO2--ETC(U)

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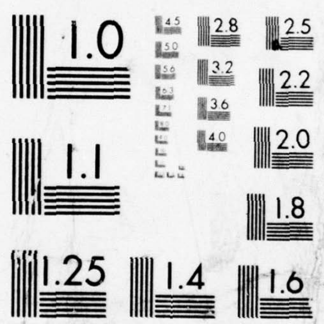

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DEFENCE RESEARCH ESTABLISHMENT

VALCARTIER

Tel: (418) 844-4271

Québec, Canada

January/janvier 1978

NON CLASSIFIE

RESUME

Ce rapport décrit une nouvelle méthode de stabilisation et d'injection dans un laser CO_2-TEA à l'aide d'un même laser pilote. Cette technique, qui utilise les deux composantes de polarisation d'un même faisceau, donne une isolation optique entre l'impulsion laser TEA et le faisceau-sonde suffisamment grande pour prévenir toute saturation ou endommagement du système de contrôle. Des impulsions à mode longitudinal unique de quelques mégawatts sont ainsi produites de façon stable et reproductible pendant de longues périodes de temps. (NC)

ABSTRACT

A novel technique that uses a single master oscillator to serve both the injection and the stabilization function in a TEA-CO_2 laser transmitter is described. The method, based on a two polarization scheme, provides sufficient optical isolation between the TEA laser pulse and the probing laser beam to prevent any damage or saturation of the controlling system. Reproducible and stable SLM operation in the MW power levels are achieved on a long-term basis. (U)

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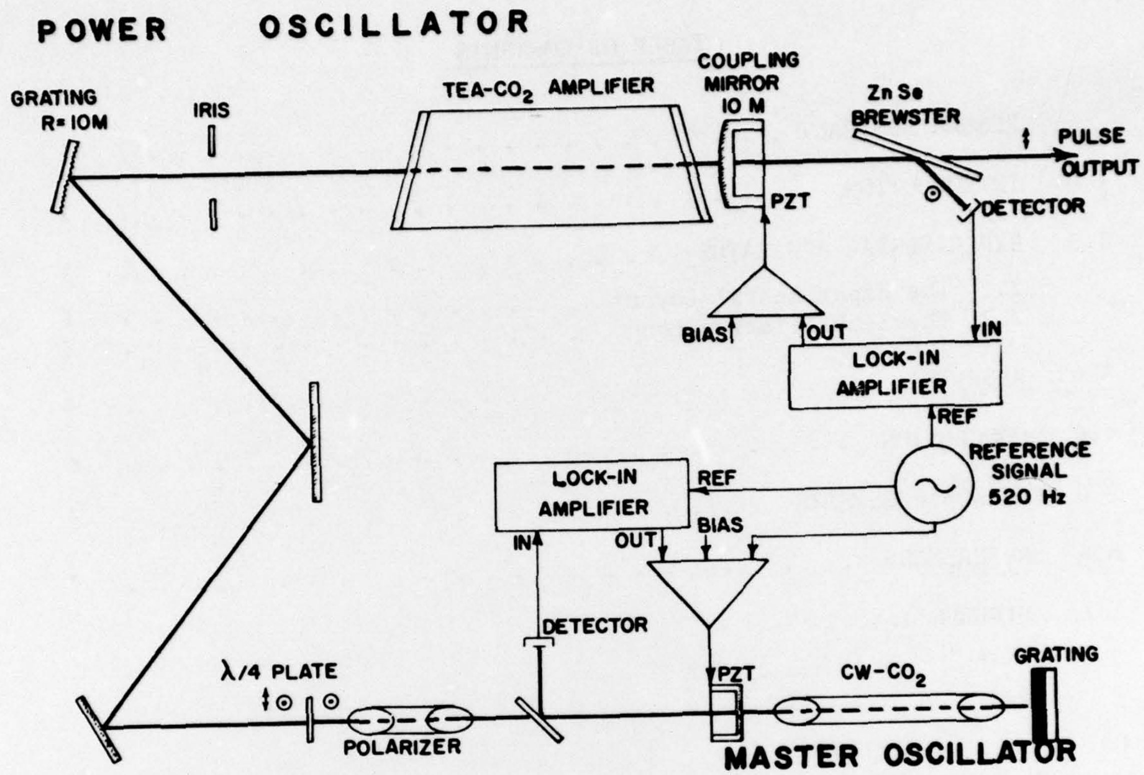


FIGURE 1 - The injection-stabilization set-up.

1.0 INTRODUCTION

Single longitudinal mode (SLM) operation of TEA-CO_2 lasers has been achieved through either interferometric mode selection [1], injection [2,3,4] or intracavity selective absorption [5] or amplification [6,7]. Among these approaches, the injection from an external source is especially attractive for high-energy and high-pulse-repetition-rate laser systems since the controlling elements are not exposed to the total radiation power.

It has been shown in a previous paper [4] that mode selection in TEA-CO_2 oscillators does not require large injection signals when the detuning frequency between the TEA cavity and the master oscillator is kept small. The purpose of this report is to present a novel injection method that ensures both cavity stabilization and longitudinal mode selection. The method uses the high isolation that can be realised between two orthogonal polarizations of a light beam. Technically, two components of mutually perpendicular polarization are derived from a CW master oscillator beam and fed through the TEA laser cavity to serve respectively the stabilization and injection functions. The work described in this document was performed at DREV between January and March 1977 under PCN 33H03 (formerly PCN 34A05) entitled: "Sources for Coherent ladars".

2.0 EXPERIMENTAL APPARATUS

2.1 The experimental Layout

The apparatus used to study this injection-stabilization scheme is depicted in Fig. 1. The master oscillator consists of a conventional CW laser stabilized in frequency through standard cavity dithering techniques. Tunable over many P and R lines of the 9.4 and 10.4 μm CO_2 transitions, it emits about one watt of linearly polarized radiation. The master oscillator beam is then passed through a Ge polarizer and is elliptically polarized by a quarter-wave plate before entering the TEA laser cavity via the zero-order of a tuning spherical grating (75 gr/mm) used in the Littrow reflection mode. The CW beam is coupled out of the TEA cavity through the convex 80% reflector and is finally split into two orthogonal components by a ZnSe Brewster plate adjusted to give full transmission at the TEA laser natural polarization. The reflected beam is received on a HgCdTe detector and the generated output is used for stabilizing the TEA resonator frequency. The power oscillator is formed by a UV preionized TEA discharge module inserted in a concave-convex cavity configuration for large mode production [8]. Separated by 1.5 m, the grating and the coupling mirror are mounted on a rigid invar structure. Sealed by two slightly tilted NaCl windows, the discharge module presents an active length of 50 cm with a clear aperture of 25 cm^2. With the iris diameter set at 1 cm, the TEA laser oscillates in the TEM_{oo} mode with an output energy of 250 mJ. This output is not optimized since the losses due to Fresnel reflections at the NaCl sealing windows exceed the 20% coupling losses of the available convex mirror.

2.2 The Stabilization Loop

The laser cavity is stabilized by maximizing the frequency-dependent transmission of the CW beam through the TEA resonator using the polarization component perpendicular to the output pulse field. The error signal is generated from coherent detection of the 520-Hz AM modulation that results from the demodulation of the wide-band-FM output of the master oscillator by the frequency-dependent transmission of the resonator. The frequency excursion of the FM modulation due to cavity dithering of the master oscillator is 1 MHz. The TEA resonator spectral transmission curve and its corresponding discriminator curve are measured by recording the detector and the lock-in amplifier output as a function of the laser cavity length. Typical curves are presented in Fig. 2 for a total PZT displacement of $\lambda/2$. The discriminator signal is then amplified and applied as a feedback to the TEA cavity translator for servo-correction. Without special care being devoted to the mechanical isolation of the cavity, a long-term stability of ± 5MHz is obtained.

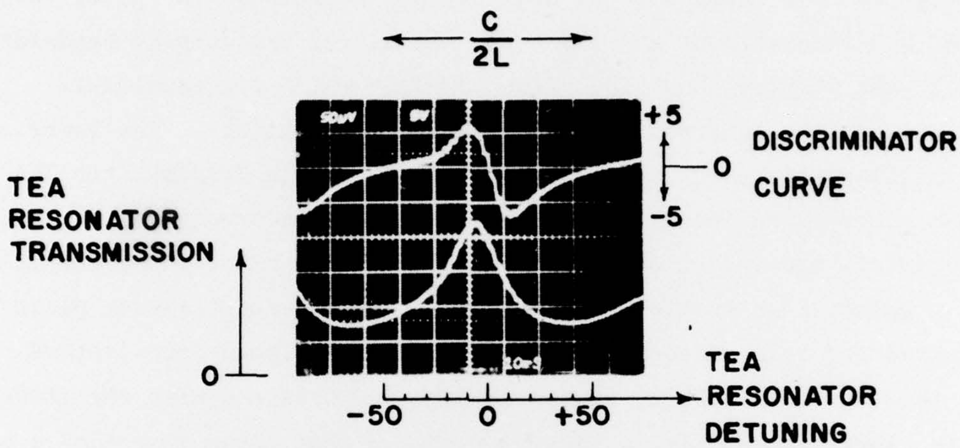


FIGURE 2 - TEA resonator spectral transmission and discriminator curve as obtained by scanning the cavity length.

3.0 RESULTS

The output TEA-CO_2 power waveforms are measured with a photon drag detector and displayed on a Tektronix 7904 oscilloscope. Typical power traces for different injection conditions are presented in Fig. 3. The upper pair of oscillograms represents the power waveforms obtained without any injection signal for two display bandwidths. The 20-MHz display shows the pulse envelope while electronically suppressing the longitudinal mode beating oscillations. The lower set of oscillograms represents, on a 500-MHz bandwidth display, the TEA laser pulse output obtained at two different injection levels. In this experiment, the injection power level in the polarization of the TEA laser pulse is controlled by simply rotating the quarter-wave plate inserted for this purpose between the master and power oscillators. All the injection results presented here are obtained with the stabilization loop closed. It is seen from Fig. 3 that, upon injecting a portion of the master oscillator in the TEA cavity, the pulse laser output is smoothed out with a decreased pulse amplitude and build-up time. The energy in the pulse, however, remains unchanged. The relative amplitude of the peak with respect to the tail of the pulse depends on the injection level; a higher injection power produces a lower peak amplitude. An injected power of 20 mW is found sufficient to produce reliable SLM operation with mode rejection in excess of 10^5 as measured from the amplitude of the beating signal. Long-term tests indicate a reproducibility of better than 99%; occasionally, a small oscillation beat was seen on the far end of the pulse envelope. However, this situation was caused by a temporary failure in the stabilization loop due to excessive vibration of the TEA cavity structure produced by mechanical noise. These instabilities could be eliminated through a more efficient mechanical isolation of the cavity and through a better design of the electronic feedback loop. Multiple exposure oscillograms of the output pulse are represented in Fig. 4 to illustrate the stability performance achieved with such a system.

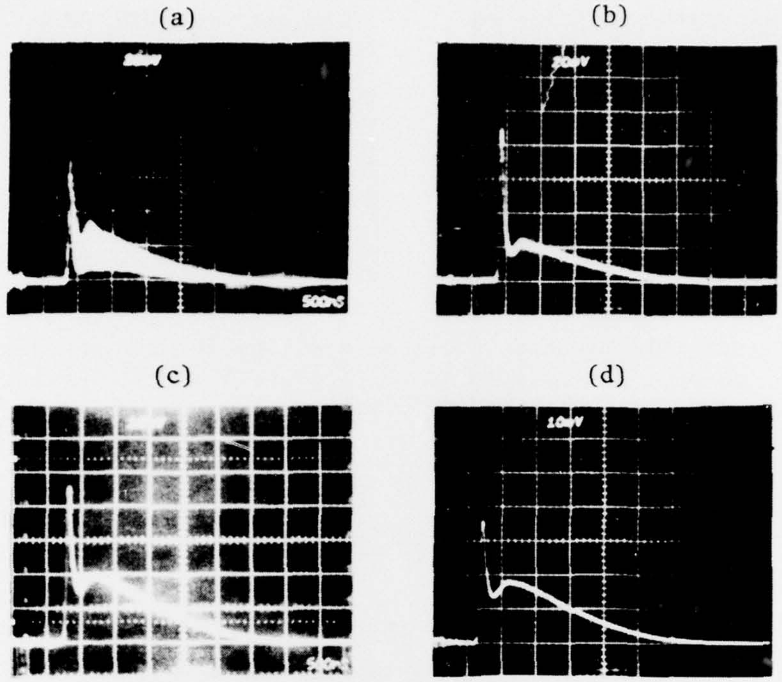
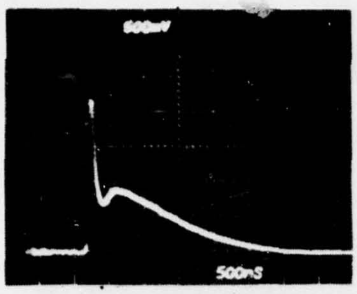


FIGURE 3 - Upper oscillograms: 500-MHz (a) and 20-MHz (b) displays of the output power waveform obtained without injection in an He-N_2-CO_2 mixture of 70-15-15 at atmospheric pressure.

Lower oscillograms: 500-MHz displays of the output power waveforms obtained with 20 mW (c) and 200 mW (d) of injected power in the TEA cavity with the stabilization loop closed.



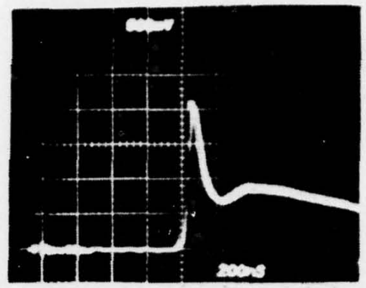


FIGURE 4 - Multiple-exposure oscillograms showing five consecutive output power waveforms obtained with 20 mW of injection power in the stabilized TEA cavity.

4.0 CONCLUSION

The advantage of the technique is that it provides sufficient optical isolation against the TEA laser output pulse and prevents any saturation or damage to the stabilization detector. In this scheme, the quality factor of the cavity is not expected to be the same for both polarizations. However, in the absence of any birefringent element in the cavity, the resonance frequencies are exactly the same so that very small detunings are automatically obtained when the stabilizing beam and the injection beam are derived from the same single-frequency laser.

The injection-stabilization technique described here can be realized with many variations; it can be applied to all types of resonators of stable or unstable geometries; the cavity frequency can be probed at either the injection or the output port of the TEA cavity; the method is not limited to internally FM modulated master oscillators: any kind of internal or external modulation on the injection laser can be used; the injection port can be a semi-transparent mirror, a grating, a perforated reflector or any other optical coupling element. On the whole, the concept appears fairly general and seems applicable to all sorts of arrangements to generate reliable single-frequency powerful laser pulse suitable for isotopic separation, optical pumping, velocimetry or coherent radar applications.

5.0 ACKNOWLEDGEMENTS

The authors wish to express their thanks to Messrs M. Noël and A. Deslauriers for their valuable technical assistance.

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